United States Environmental Protection Agency **Office of Research and Development**

National Exposure Research Laboratory
Research Abstract

Government Performance Results Act (GPRA) Goal 4
Annual Performance Measure 265

Significant Research Findings:

Demonstration of a Coupled Plant-Soil-Deposition Model to Improve Deposition Modeling

Scientific Problem and Policy Issues

The EPA operates the Clean Air Status and Trends Network (CASTNET) to monitor the status and trends of air pollutant emissions, ambient air quality, and pollutant deposition at over 200 sites across the country. Deposition estimates are important in assessing the overall pollutant loadings to ecosystems, an important aspect of ecological assessments. To obtain estimates of deposition flux, measured concentrations are paired with model-predicted deposition velocities. The model currently used to predict the deposition velocity is the NOAA Multilayer Model (MLM). Earlier testing of this model showed the sensitivity of the modeled deposition velocity to leaf area index. Leaf area index (LAI) and canopy height are not routinely measured at CASTNET sites and are currently modeled using a step-function that is based on measurements made in 1991-1992, and 1997 and depend only on the day of the year. Thus, the same annual leaf-out profile is used each year, whereas actual LAI values respond to variations in rainfall, temperature, radiation, etc. Given the sensitivity of the deposition model to LAI, obtaining better estimates of LAI should provide more realistic estimates of deposition flux.

Research Approach

Site-specific, interannual variations in LAI could be obtained from various sources for input to dry deposition models. Remote sensing data offers promise, but is not currently available at the scales needed for CASTNET. Alternatively, plant growth models can be used to predict the response of plants to interannual variability in meteorological conditions. There are many different approaches to plant growth modeling ranging from simple parameterizations to more complicated photosynthetically- based models. We selected the Erosion Productivity-Impact Calculator (EPIC) model for use in this project because of its relative simplicity and long history of use in the agricultural community. EPIC predicts plant growth as a simple function of accumulated heat units which depend on temperature. The deposition model selected for this project is the Multilayer Biochemical Model (MLBC). The MLBC model is under development as a replacement for MLM, the current model use for determining deposition velocity for CASTNET. The plant growth algorithm was extracted from EPIC and embedded within MLBC. This version of MLBC is denoted as MLBC-PG. In MLBC-PG, the meteorology used as input for the deposition model is also used for the plant growth algorithm. Water and temperature stress factors calculated by the deposition model for determining canopy resistance were used in the plant growth algorithm. The LAI and canopy height determined from the plant growth algorithm are used in the deposition model for determining pollutant deposition velocities.

Results and Impact

The plant growth algorithms from EPIC were imbedded within MLBC-PG to provide an optional method for determining LAI and canopy height. MLBC-PG was run for the CASTNET site in Bondville, IL which was also the site of an intensive field study during which LAI, canopy height, and deposition fluxes were measured. The predominant plant type at this site is corn. The values of the LAI and canopy height calculated by MLBC-PG are in good agreement with those calculated by EPIC run as a stand-alone model showing that the plant growth algorithms were correctly imbedded within the deposition model. MLBC-PG was run for 3 years of meteorological data from the Bondville CASTNET site. LAI values calculated by MLBC-PG show interannual variations in LAI whereas the step-function provides the same LAI profile each year. The canopy height curves are particularly different in that the CASTNET step function decreases the canopy height during senescence whereas MLBC-PG holds the canopy height at the maximum value until harvest which is more realistic. Hourly deposition velocities calculated using the plant growth algorithms were 5-10% different than those calculated using the traditional CASTNET LAI values, with greater differences occurring for years with more extreme meteorology. Initial comparisons of LAI values generated by the plant growth algorithm against the field study data show substantial differences in the plant growth curves. Adjustments of the input parameters such as planting data and heat units needed for maturity allow a better match between the modeled and measured values, illustrating the sensitivity of the plant growth model to these plant parameters. Additional model runs for other CASTNET sites show similar results.

These results are a first step in trying to provide better characterizations of plant growth to deposition models, which can result in better estimates of deposition flux. MLBC-PG shows promise in being able to predict appropriate LAI and canopy height curves that are responsive to the meteorology. However, more work needs to be done to study the sensitivities of this model and to determine the appropriate plant parameters for use in CASTNET on an operational basis. Additionally, this project sets the stage for further work in coupling models from different disciplines.

Research Collaboration and Research Products

Dr. Ellen Cooter (NERL/AMD) collaborated on this research, providing valuable insight in plant growth modeling.

Future Research

The MLBC model is currently under development for use in CASTNET. While the model has been applied and evaluated for intensive field studies, modifications are needed to use the CASTNET input data and to specify plant parameters for network sites. Research is being performed by NERL’s Landscape Characterization Branch on obtaining LAI estimates via remote sensing. The development of alternative methods for determining LAI and canopy height for input to the model will depend on client needs.

Contacts for Additional Information

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